University of Maine

Maine Agricultural Experiment Station

ORONO

BULLETIN 307 SEPTEMBER, 1922

STERILITY RELATIONSHIPS IN MAINE APPLE VARIETIES.

CONTENTS

MAINE
AGRICULTURAL EXPERIMENT STATION
ORONO, MAINE

THE STATION COUNCIL

PRESIDENT CLARENCE C. LITTLE,	*President*
DIRECTOR WARNER J. MORSE,	*Secretary*
ORA GILPATRICK, Houlton,	*Committee of Board of Trustees*
THOMAS E. HOUGHTON, Fort Fairfield,	*Committee of Board of Trustees*
FRANK E. GUERNSEY, Dover,	*Committee of Board of Trustees*
FRANK P. WASHBURN, Augusta,	*Commissioner of Agriculture*
EUGENE H. LIBBY, Auburn,	*State Grange*
WILSON H. CONANT, Buckfield,	*State Pomological Society*
JOHN W. LELAND, Dover,	*State Dairymen's Association*
LEONARD C. HOLSTON, Cornish,	*Maine Livestock Breeders' Ass'n.*
WILLIAM G. HUNTON, Portland,	*Maine Seed Improvement Ass'n.*

AND THE HEADS AND ASSOCIATES OF STATION DEPARTMENTS, AND THE DEAN OF THE COLLEGE OF AGRICULTURE

THE STATION STAFF

ADMINISTRATION	WARNER J. MORSE, PH. D.,	*Director*
	CHARLES C. INMAN,	*Clerk*
	MARY L. NORTON,	*Clerk*
	ILA K. WHITE,	*Clerk*
BIOLOGY	JOHN W. GOWEN, PH. D.,	*Biologist*
	KARL SAX, SC. D.,	*Biologist*
	MARJORIE GOOCH, M. S.,	*Assistant*
	MILDRED R. COVELL,	*Clerk*
	BEATRICE WEBSTER,	*Laboratory Assistant*
CHEMISTRY	JAMES M. BARTLETT, M. S.,	*Chemist*
	ELMER R. TOBEY, CH. E.,	*Associate*
	C. HARRY WHITE, PH. C.,	*Assistant*
ENTOMOLOGY	EDITH M. PATCH, PH. D.,	*Entomologist*
	ALICE W. AVERILL,	*Laboratory Assistant*
PLANT PATHOLOGY	WARNER J. MORSE, PH. D.,	*Pathologist*
	DONALD FOLSOM, PH. D.,	*Associate*
	VIOLA L. MORRIS,	*Laboratory Assistant*
AROOSTOOK FARM	.....	*Associate Biologist*
	PERLEY H. DOWNING,	*Superintendent*
HIGHMOOR FARM	.....	*Scientific Aid*
	WELLINGTON SINCLAIR,	*Superintendent*

BULLETIN 307

STERILITY RELATIONSHIPS IN MAINE APPLE VARIETIES.[1]

KARL SAX

SUMMARY

1. Apple blossoms emasculated by removing the anthers and petals and left exposed to wind and insects will rarely set fruit because wind is not effective in cross-pollinating apples, and insects do not visit flowers which have no petals. This knowledge is of value in cross-pollination work.

2. For practical purposes all commercial varieties of apples grown extensively in Maine are self-sterile and must be pollinated with pollen of compatible varieties to set a normal crop.

3. The sterility relationships of all combinations of the following varieties have been determined,—Ben Davis, Baldwin, Golden Russett, Rhode Island Greening, Northern Spy and McIntosh. Some results are also presented for Delicious, Wealthy, Gravenstein and Red Astrachan.

4. With the exception of Greening and also the Baldwin as the pollen parent, any combination of the first six varieties noted above are inter-fertile.

5. Insects are absolutely essential in transmitting pollen from one variety to another, but good crops have been obtained in large blocks of self-sterile varieties where bumble bees were apparently the only pollinating agencies. However, honey bees are desirable to insure an adequate set of fruit and under some conditions are probably indispensable.

6. Under conditions at Highmoor Farm (and these conditions are undoubtedly typical for a large part of New England) a relatively small number of early blooming horticultural varieties and "natural" apple trees are sufficient to provide pollen for a large block of self-sterile trees. These results may be due to factors peculiar to New England—viz, the presence of scattered "natural" trees in pastures and wood lots adjacent to orchards, and conditions unusually favorable for bumble bees. In general,

[1]Papers from the Biological Laboratory, Maine Agricultural Experiment Station, No. 152.

however, it would be advisable to inter-plant varieties known to be compatible with each other although the blocks of trees need not be too small for convenience in harvesting. The addition of a number of compatible early blooming varieties would be of value and, in case only a single commercial variety is desired, the presence of a few early blooming pollen varieties scattered throughout the orchard would insure a better set of fruit.

INTRODUCTION

It is well known by horticulturists that most apple varieties are self-sterile and that for good sets of fruit provision must be made for pollen varieties and for the transmission of pollen from tree to tree. A knowledge of what varieties are inter-fertile is necessary in selecting those to be planted together or for top working certain trees in large blocks of self-sterile varieties. Most investigators have concluded that honey bees are essential for carrying pollen from one variety to another.

A list of self-sterile and self-fertile apple varieties and those known to be inter-fertile has been published in bulletin 287 of the Maine Agricultural Experiment Station. In this bulletin are included sterility relationships of varieties grown in all parts of the country, but complete records are not available for some of the most important varieties grown in Maine. In some cases the conclusions were tentative, as they were based on insufficient numbers. It is also evident from recent work that local conditions peculiar to New England may make unnecessary certain recommendations which may be applicable to other regions.

The present work on sterility relationships in apples is limited to the more important varieties grown in Maine so far as they are available at Highmoor Farm. These varieties are Ben Davis, Baldwin, Golden Russett, Rhode Island Greening, Northern Spy and McIntosh. Four of those recommended by the extension department are included in this list, but three other varieties, Delicious, Wealthy and Gravenstein were not yet available for experimental work. Some data on these varieties have been obtained from other stations.

Methods

The usual methods of emasculating and pollinating the apple blossoms were used in 1920. The petals and anthers of the flowers were removed with forceps before the bud was open. The flowers were then protected from accidental cross pollination by covering them with paper bags. In a day or two after emasculating the bags were removed and pollen of a given variety brushed on the stigmas with a camel's hair brush. When the fruit set the paper bags were removed and replaced with cheese cloth bags. Pollen was obtained by picking buds about to open and removing the anthers. The anthers placed on a sheet of paper in a warm room soon dehisced and were then poured with the pollen into a small vial.

In 1921 another method of crossing was tried with good results and which enabled a much larger number of flowers to be worked. The method of emasculating has been used by a number of investigators working with apples, plums, and pears. The thumb nail is inserted beneath the calyx and with the aid of the fore finger the sepals, petals and anthers are removed with one operation. This method of emasculating is illustrated by the diagramatic cross section of an apple blossom shown in Figure 1.

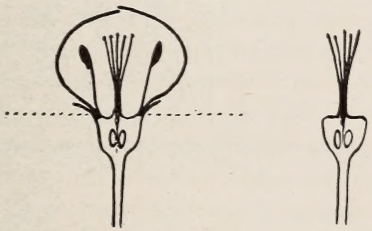

Fig. 1. Diagramatic cross section of apple blossom showing method of emasculating bud by removing anthers together with petals, stigmas, and sepals.

It has long been known that wind is not effective in cross-pollinating apple blossoms. It has also been shown by Lewis and Vincent (8) that bees and other insects rarely visit apple blossoms from which the petals have been removed. It is obvious then that it should be unnecessary to bag the emasculated blossoms to avoid accidental or uncontrolled pollination. However,

all previous investigators have considered it necessary to protect the emasculated blossoms with paper bags.

For the past two years the blossoms have not been protected after emasculation in our crossing work with apples. On each tree used as the seed parent a check branch was left with 50-100 emasculated blossoms which were not protected from wind or insect pollination (except that the petals were removed by the method of emasculation and thus apparently excluded insect visitors) and which were not hand pollinated. The results from these checks are shown in Table 1.

TABLE 1.

Check on Method of Emasculating and Pollinating Apple Blossoms. Flowers Emasculated and Exposed to Insects and Wind for Pollination.

	No. of Flowers Emasculated		No. of Fruit Set	
	1921	1922	1921	1922
Golden Russett D-8	87	396	0	3
McIntosh H.O.†	69		24	
Greening F-1	71	132	0	0
Baldwin C-42	188	48	0	1
Ben Davis	132	38	0	0
Spy	84	153	4	3
Crab H.O.		202		0
Red Astrachan H.O.		132		0
McIntosh 27-1		135		2
Golden Russett D-17*		141		65

*Emasculated by removing anthers only, petals not removed.
†Tree closely surrounded by compatible pollen varieties.

It is evident that with two exceptions practically no apples set when the emasculated blossoms were dependent on wind and insect transmission of pollen. In case of the McIntosh in 1921 the relatively high set of fruit is probably due to the fact that this tree is closely surrounded by several different varieties and the branches interlock to some extent. The presence of many varieites of trees in close proximity in the "home orchard" would facilitate wind pollination. In 1922 a McIntosh tree in the Ben Davis No. 2 orchard was used and altho the McIntosh was surrounded by the compatible Ben Davis trees (set 25 feet apart) an insignificant amount of fruit set on the check branch. The high per cent of set on the Golden Russett D-17 supports the

conclusions that bees visit only flowers with petals present. The 141 blossoms were emasculated by removing the anthers only and the large set of fruit shows the value of the petals in attracting insects. These check experiments show that a very small per cent of fruits develop from blossoms emasculated in the manner described even when unprotected by bags. The experimental error is probably no larger than in cases where the blossoms are protected with bags.

Under favorable conditions several thousand blossoms can be emasculated per day. Usually the blossoms were not pollinated for one or two days after emasculation, but they can be pollinated at once with good results. The flowers on a single branch were all pollinated with the same variety of pollen and each cross was given a number. A record of the number of pollinations for each cross was made with the aid of a small counting machine which was held in the hand with the pollen brush. The fruit set was determined shortly after the June drop and also at harvest time. A desirable feature of the above described method of emasculation is that all crossed apples have no calyx on the mature fruit and any open pollinated fruits that may accidentally develop are easily detected at harvest time.

At the beginning of the work the blossom clusters were not thinned but in 1921 and 1922 each cluster was thinned to one blossom or about 80 per cent of the flowers were removed. The desirability of thinning the blossoms was shown by the results of an experiment performed on a Ben Davis tree in 1920. Two branches of about equal size were selected for comparison. On one branch there were 630 flowers and 266 or 42 percent of these set fruit. The apples were thinned to 63 fruits before the June drop and 41 apples developed. The other branch bore 555 flowers and 278 or 50 percent set fruit. These apples were not thinned and 40 of them developed to maturity. The thinning of the fruit before the June drop caused a much higher percentage of fruit to develop (65.1%) than in case of no thinning (14.4%). In both cases only about 7 percent of the blossoms set fruit and yet these branches bore all that they could mature properly. This is in accord with Heinicke's (6) conclusions that a set of 3 to 7 percent will produce a normal crop. Since each cluster base develops but a single apple as a rule there is little use in working all the flowers,—especially if seeds or mature fruits are desired. When the flowers are thinned to one blossom per cluster base a

much higher percentage of fruit develops to and the results are probably more uniform. The normal set,—i.e., the set obtained from open pollinated blossoms which have not been emasculated—was 6.8 percent for the Ben Davis in 1920, 7.5 percent in 1921 and 11.8 percent for 1922. Since the blossoms were thinned to one per cluster the set of apples which survive the June drop will be much higher than for unthinned clusters, and therefore the apples set per cluster under natural conditions will probably be a more accurate measure of a normal set with which to compare the set obtained on crossing. On this basis the normal set for the Ben Davis was 37 percent in 1921 and 59 percent in 1922. The use of different trees in different years undoubtedly will cause some variation as well as climatic conditions and abundance of bloom. In all cases only vigorous trees were used and with very few exceptions the trees worked carried an abundant bloom.

The crossing was done at Highmoor Farm. The trees were 25-30 years old and in good condition. The writer has been assisted in this work by H. C. McPhee, former Scientific Aid, Miss Marjorie Gooch, Assistant in Biology, and Dr. Hally J. Sax.

STERILITY RELATIONSHIPS

The results of the self- and cross-pollinating work for the past three years are shown in Table 2. The table is so arranged that the efficiency of a given variety either as a blossom parent or source of pollen can be determined readily. For instance the Baldwin is fertile with all pollen except its own and Greening, but Baldwin pollen has not given satisfactory results with any of the other varieties as seed parents. The compatibility of any combination is readily found. For instance Baldwin pollinated with Russett pollen gave 39 percent set from 102 blossoms pollinated in 1920, and in 1921 and 1922 the set was 50 percent and 13 percent respectively. This combination Baldwin x Russett is considered sufficiently fertile for practical purposes and is so indicated by the mark.* Combinations not so marked are not considered sufficiently inter-fertile to insure an adequate set of fruit for commercial purposes. The percentage of set was based on blossoms which developed into mature fruit or at least survived the June drop. In 1920 the counts were made in the autumn and any apples which fell prematurely were held in the cloth bags. In 1921-22 the counts of fruit set were made shortly

after the June drop. Since some of the apples fell before maturity the percent set was somewhat less than the percent developed, but where the blossoms were thinned this difference was not great. The percent set was used as an index of fertility rather than percent developed because the latter factor would vary more with differences in tree vigor and climatic conditions.

TABLE 2.

Results of Cross- and Self-Pollination.

Seed Variety	Tree No.	Year	Number	Pollen Variety						Total Crossed
				Ben	Baldwin	Russett	Greening	Spy	McIntosh	
Ben Davis	2-26	1920	Flowers	1214	276	286	291	179	503	1535
			% Set.	0.6	0	4.	0.7	13.	9.	
	1-19	1921	Flowers	481	134	331	144	435	612	1656
			% Set.	0	7	44.	6.	62.	70	
	1-28	1922	Flowers		105	203	202	155	168	833
			% Set.		4.	*41.	3.	*39	*33	
Baldwin	C-42	1920	Flowers	417	1754	102	61	103	76	759
			% Set.	33.	0.9	39	1.	53.	38.	
	7-6	1921	Flowers	949	126	66	110	157	128	1410
			% Set.	47	0	50	1	67	54	
	C-42	1922	Flowers	48	70	127	171	27	22	395
			% Set.	*62	0	*13	6	*37	*41	
Russett	D-8	1920	Flowers	214	84	917	97	101	102	598
			% Set.	5.	1.	0	0	4.	2.	
	D-5-7	1921	Flowers	388	428	50	200		299	1315
			% Set.	57.	6.	8.	34.		46.	
	D-18	1922	Flowers	141	154	272	50	64	96	505
			% Set.	*25.	1.	0	*4	*19	*7.	
Greening		1920	Flowers	64	52	112	95		75	203
			% Set.	3.	0	0	0		1.	
	F-1-2	1921	Flowers	806	273	192	135	319	277	1867
			% Set.	5.	0	0	0	0	0	
	F-1	1922	Flowers	95	50	112	105	106	64	427
			% Set.	0.	0	0	0	0	0	
Spy	F-13	1920	Flowers	105	79	74	79	618	73	410
			% Set.	30.	6.	13.	1.	0	39.	
	A-22	1921	Flowers	60	123	85	55	99	892	1215
			% Set.	27.	0	24	7.	0	31	
	A-22	1922	Flowers	157	30	156	85	41	115	543
			% Set.	*6.	0	*7	0	0	*2	
McIntosh	HO	1920	Flowers	109	59	70	49	49	1025	386
			% Set.	18.	7.	1.	10.	22.	0.2	
	HO	1921	Flowers			120	153	134	94	407
			% Set.			2	3	75.	34‡	
	27-1	1922	Flowers	46	120	81	53	30	28	330
			% Set.	*13	17.	12	19	*7.	0	

*Classed as inter fertile.
‡Data unreliable because check branch had 35% set.

Previous investigations have shown that most apple varieties are self-sterile and that only a small percentage are completely self-fertile. The results of our studies show that all of the

varieties used are almost or completely self-sterile. From a commercial standpoint it would be safe to class all of the leading apple varieties as self-sterile under Maine conditions. In certain localities the Baldwin and McIntosh are reported as partially self-fertile indicating that fertility is dependent to some extent on environmental conditions. In 1921 the McIntosh shows 34 percent set on selfing, but the check branch set 35 percent of the blossoms emasculated, indicating wind or insect pollination, so the McIntosh data for 1921 is not reliable, except perhaps for negative results. It has been suggested that pollen from other trees of the same variety might be effective but this test has previously been made with negative results. Additional work along this line was done with the Ben Davis. In 1921 a Ben Davis tree was pollinated with pollen from 9 different trees of the same variety. From 316 pollinations only 2 apples set. In 1920 the selfed blossoms were simply bagged but for the past two years all selfed flowers were hand pollinated.

Additional data on self-sterility are available for the Delicious, Wealthy, and Gravenstein. Morris (6) reports Delicious and Wealthy as self-sterile in Washington while Gravenstein is patricularly self-fertile. In California, however, the Delicious is said to be self-fertile. In Minnesota (4) Delicious and Wealthy are both self-sterile and Delicious is classed as self-sterile in Illinois (3). In Maryland (2) Wealthy is classed as self-fertile. Under Maine conditions all of these varieties are probably self-sterile.

In judging the fertility of a given combination of varieties it is necessary to consider the normal set. For the Ben Davis the normal set was 37 percent in 1921 and almost 60 percent in 1922. In 1920 it was 48 percent for Ben Davis, 36 percent for Baldwin and Russett and 55 percent for McIntosh. In general a set of approximately 30 percent in case of thinned blossoms can be considered satisfactory. On this basis more than half of the combinations given in Table 4 are inter-fertile. Ben Davis is fertile with Russett, Spy and McIntosh. Greening is slightly fertile with Ben Davis but completely sterile with all other varieties used. Spy is successfully pollinated with Ben Davis, Russett and McIntosh while McIntosh is fertile with Ben Davis, Spy and perhaps Baldwin, and Greening and Russett.

It has been generally considered that it is safe to plant almost any combination for purposes of cross-pollination, provided that they blossom at the same time. Gowen (5) has found that in 243 combinations 57 were not compatible but only about half of the infertile crosses were made in sufficient numbers to be of much value. Most of the sterile combinations include members of the Winesap group. This same group is general inter-sterile with other varieties in Washington (9) and Maryland (2). With the exception of the Winesap group most any two varieties have been found to be inter-fertile. However, no such results have been obtained in Maine, even when large numbers of blossoms have been pollinated for several years and under various climatic conditions. The Greening is completely sterile with all pollen varieties used except Ben Davis and with Ben Davis pollen it is only slightly fertile. When open pollinated the Greening set a very good crop in 1921 but it is an alternate bearing tree at Highmoor Farm and bore little fruit in 1920 and 1922. Baldwin pollen is not very compatible with any variety and is of possible economic value only in case of the McIntosh. From 30-50 percent of the Baldwin pollen is imperfect, but this factor is probably not the cause of sterility because about 50 percent of McIntosh pollen is poor and yet McIntosh is one of the best pollen varieties. Other inter-sterile combinations are found when Greening is used as the pollen parent, only the Russett and perhaps McIntosh set an appreciable amount of fruit with Greening pollen. More than 75 percent of the Greening pollen was morphologically perfect. Altogether more than a third of the combinations used are sufficiently inter-sterile to be of little practical value for purposes of cross-pollination. The greater degree of compatibility of apple varieties previously reported may be due to more favorable climatic conditions or more vigorous trees, to inadequate numbers of pollinations for conclusive results, or perhaps a relatively small set was considered adequate to class a given combination as inter-fertile. Certainly some of these factors are the cause of the larger percentage of inter-fertile combinations reported in many cases, altho varietal differences and especially the incompatibility of the Greening is partly responsible for the smaller degree of inter-fertility here reported.

In addition to the above crosses a few others have been made especially with certain common early varieties and with "natural" trees as the pollen parent. These crosses were made primarily

for a special problem in pollination which will be considered later. The following combinations were found to be inter-fertile: McIntosh with Red Astrachan pollen, Ben Davis with Red Astrachan, Ben Davis with "Natural," Ben Davis with Duchess, Baldwin with Duchess, and Spy with Duchess. In Washington (9) Gravenstein is fertile with Red Astrachan, Yellow Transparent, McIntosh and Delicious pollen. Dorsey (4) reports the following combinations as inter-fertile in Minnesota: Delicious x Wealthy, Duchess x Delicious, Wealthy x Delicious, and Wealthy x Wolf River.

It is evident from a study of Table 3 that the percent of set, using the same trees and the same parental combination, may vary greatly from year to year. In the Ben Davis and Baldwin the difference is not so great as in other varieties when the method of crossing was the same, as was the case in 1921 and 1922. The Ben Davis is a regular bearer and Baldwin trees were selected which were heavily loaded with blossoms. In case of the Spy and Russett there was a light bloom on the trees used, especially on the Spy in 1922. A comparison of fruit set in 1921 and 1922 on the Spy when pollinated with McIntosh shows the result of using a tree in its "off year."

TABLE 3.

Identical Crosses on Various Branches of Individual Trees to Show Variation in Fruit Set. 1921.

	Cross No.	Flowers Poll.	Fruit Set	% Set
Baldwin 7-6 x Ben Davis 1-19	67	132	55	42
Baldwin 7-6 x Ben Davis 1-19	68	79	45	57
Baldwin 7-6 x Ben Davis 1-19	69	67	22	33
Baldwin 7-6 x Ben Davis 1-19	70	66	41	62
Baldwin 7-6 x Ben Davis 1-19	71	125	28	22
Baldwin 7-6 x Ben Davis 1-19	72	212	103	49
Ben Davis 2-19 x Spy F 13	81	46	41	90
Ben Davis 2-19 x Spy F 13	84	144	70	48
Ben Davis 2-19 x Spy F 13	85	29	20	70
Ben Davis 2-19 x Spy F 13	86	53	40	75
Ben Davis 1-20 x Spy F 13	87	138	94	68
Spy A-22 x McIntosh	123	41	8	20
Spy A-22 x McIntosh	126	47	28	60
Spy A-22 x McIntosh	130	70	18	26
Spy A-22 x McIntosh	131	98	63	64

Even on the same tree different branches pollinated with the same pollen may vary greatly in percent of set. A summary of a

number of crosses on Baldwin, Ben Davis, and Spy are shown in Table 3. Each cross number represents a branch. The set on branches of Baldwin 7-6 varied from 22 to 62 percent, and similar differences are found in Ben Davis and Spy. In most cases the number of flowers worked was large enough to prevent much variation due to random sampling. These results emphasize the necessity of using large numbers of flowers and extending the work over several years.

Sterility as an Orchard Problem.

Most apple varieties are undoubtedly self-sterile and must be pollinated with pollen of a compatible variety to set good crops. The orchardists' problems are then. 1. What varieties should be planted together? 2. How close together should the different varieties be planted? 3. What provision must be made to transmit the pollen from one variety to the other? The last problem will be considered first.

Practically all horticulturists are agreed that insects, especially honey bees, are necessary to cross-pollinate apple blossoms. There is sufficient evidence to exclude the possibility of wind pollination. Alderman (1) has shown the value of honey bees in increasing the set of fruit in West Virginia. Branches of pollen varieties were placed in pails of water in a block of 16 Rome Beauty trees which are self-sterile. Six hives of bees were placed in this block. The percent of set was 12.6 percent in the plot with bees and pollen varieties, as compared with a set of 7.8 percent in a check plot. The check plot produced only half as much fruit as the plot with bees in it. A second year's test gave more set for bee plots, but the yield was practically the same as for the check plots. The value of the above experiment may well be questioned because a set of 5 to 7 percent with a normal bloom is sufficient to produce all the fruit that a tree can develop to maturity, and a set of 12.6 percent should be of little advantage in ultimate yield. The higher set in both years in the bee plots and near a Ben Davis tree is perhaps significant, but the increased number of bees and the introduction of branches of pollen varieties were apparently not influential in increasing yields.

The work of Tufts (11) with pears in California show beyond question the beneficial effect sof cross-pollination both

for increased set of fruit and increased yields. Pollenizing agencies such as bees were also found necessary in almond orchards (10). Hendrickson (7) finds bees of much value in plum orchards even where the variety is self-fertile.

On the other hand Morris (9) in speaking of honey bees as cross-pollinating agents states that, "Their abundance and great activity seem to justify the conclusion that they are very important pollen conveyors, but we have not been able to find conclusive evidence that they are a necessity for successful cross-pollination . Bees travel long distances in visiting blossoms, but in many sections of Washington there have been many orchards fruiting quite satisfactorily without any tame bees known to be within several miles."

Further evidence that good crops may set even in large blocks of self-sterile varieties is available from observations at our experimental farm in 1921. The apple trees blossomed about May 15th, some varieties a day or two earlier and some a day or two later. The Ben Davis trees were in full bloom on May 19th. On May 22 a severe wind storm removed practically all of the remaining petals from all varieties except the Spy. For the Ben Davis trees the bloom period extended from May 15 to May 22. During this entire period the weather was very cold and windy, thus preventing the honey bees from traveling far from the hives. The hives of bees were kept in the small Home orchard which contains 15 or 20 different varieties of apples. During the blooming period honey bees were observed only in this Home orchard and in the Russett orchard about 200 feet away. No honey bees were observed in the Ben Davis orchard, which is about a quarter of a mile from the Home orchard during the period of bloom. Occasional bumble bees were seen in all orchards but no other insects could be found pollinating the apple blossoms. In this large block of self-sterile Ben Davis trees a satisfactory set of fruit was obtained and an unusually good crop was harvested, and yet pollination was effected only by bumble bees. Possibly a few honey bees were present but none could be seen during the time we were working in the orchard.

Closely associated with the agencies for cross-pollination is the second factor,—the interplanting of compatible varieties. It has been generally recommended that inter-fertile varieties should be planted in alternate strips of four or five rows of each variety

in a block or a small percentage of pollen varieties be evenly distributed thruout the orchard.

Morris (9) work with Washington varieties shows that about 34 percent of the combinations tried were completely inter-sterile and about 18 percent were nearly inter-sterile (usually the sterile combinations included the Winesap). But even with such inter-sterility of varieties and presumably without a great mixture of varieties Morris finds that, "In all of the enquiries made in visiting the orchards and in correspondence, there has not been found an orchard containing two or more of the common commercial varieties here listed that is showing indications of failure due to self-sterility or inter-sterility of varieties."

Evidence from work at Highmoor also shows that large blocks of self-sterile trees may set a normal crop even when no compatible pollen varieties are within several hundred yards. (See p. 81, Bull. 298). Especially interesting is the behavior of the Greening trees at Highmoor. It has been shown that the Greening is almost completely self-sterile with all pollen varieties used, but the Greening trees produced good crops in 1921 and in 1919. For instance Greening F_1 produced 541 pounds of apples in 1919, no fruit in 1920 and in 1921 it produced 497 pounds, even though a considerable portion of the tree was used for crossing work. The only available compatible (?) pollen varieties were the few trees in the Home orchard about 500 feet away and a few scattered varieties and "Natural" trees at greater distances. Furthermore the pollination was effected largely if not entirely by bumble bees in 1921.

The question naturally arises: How are blocks of self-sterile varieties so thoroughly pollinated even when honey bees are unable to work? In 1922 observations were made on the activity of insects in pollinating the apple blossoms. The honey bees were very abundant and were undoubtedly the chief agencies in effecting cross-pollination. The bumble bees were next in importance. In the Ben Davis orchard they would average at least two per tree during the height of the blooming period. Although the bumble bees were not nearly so numerous as the honey bees they were much more efficient as individuals. The honey bee "worked" only about 6 flowers per minute while the bumble bee visited about 20 flowers per minute. At this rate a bumble bee could pollinate several trees per day even assuming that half of the time was spent on varieties other than those

being pollinated. Among the less important blossom visitors were found species of two genera of the mining bees, *Andrena nubecula* and *Halictus paralellus,* a leaf-cutter bee *Megachile latimanus,* a species of *Nomada* and an occasional Syrphid fly.*

The bumble bee is undoubtedly an important factor in cross-pollinating apple blossoms under most Maine conditions. In cold and windy weather the bumble bee is able to work when the honey bee is not able to travel far from the hive. When orchards are in sod the bumble bees make their nests thruout the orchard. Even if the orchard is cultivated, it is usually surrounded by untilled pastures or wood lots well suited for nests of bumble bees.

The evidence indicates that pollen fertile with the Ben Davis has been supplied by comparatively few trees. The total number of Ben Davis trees, until recently, was more than 1500 in the two adjacent orchards. Recently one orchard was partially top worked with McIntosh but the latter have blossomed only during the past three years. Most of the other varieties on the farm are Baldwins which are not fertile on the Ben Davis. There are about 25 Russetts, a few Spys, several McIntosh and about 20 odd varieties, often a single branch of a variety grafted in an old tree, in the Home orchard. Altogether there were probably less than a hundred trees of varieties compatible with Ben Davis —including "Natural" trees—within a half mile radius of the Ben Davis orchards. And yet in 1914 the trees in Ben Davis orchard No. 1 averaged 175 pounds of fruit per tree which was a good crop considering the size and condition of the trees. Good crops have been obtained on an almost solid block of over 1500 self-sterile Ben Davis trees with comparatively few good pollen varieties and the latter at an average distance of a quarter of a mile from the Ben Davis orchard. How is it done?

Most of the "natural" trees and varieties in the Home orchard, such as Transcendent Crab, Red Astrachan, Duchess, and Yellow Transparent, blossom earlier than the standard commercial varieties. Naturally the bees, both honey bees and bumble bees, visit these varieties first. It is possible that the bees not only become covered with compatible pollen of early varieties, but perhaps deposit the pollen in the hives and nests so that between visits to the later blooming varieties they become con-

*These insects were identified by Dr. Edith Patch.

taminated with the pollen previously collected. At any rate it appears that a few early blooming varieties and natural trees can provide sufficient pollen for good sets of fruit at least under local conditions. Natural trees are especially valuable for pollen because they bloom early and abundantly and since they are seedlings the chances are that most of them will be sources of a compatible pollen supply for most commercial varieties.

Recommendations

From the above results it might appear that the horticulturist has no sterility problems with apple varieties grown in Maine. However, it would be advisable to make provision for cross pollination in setting out an orchard. This does not mean that varieties be greatly mixed in planting, but blocks of compatible varieties should be planted which are not too small for efficient harvesting. Nor would it be advisable to plant blocks of inferior varieties or varieties unsuited to soil and climatic conditions simply because they are good pollen varieties. With the exception of Greening and Baldwin as a pollen parent, any two varieties considered in this bulletin can be planted together with good results so far as inter-fertility is concerned. With the exception of Spy the blossoming periods of these varieties overlap sufficiently for cross-pollination. Spy is not too late to be pollinated by the other varieties but probably would not be of much value as a source of pollen. Spy and McIntosh are especially compatible varieties and they are also excellent commercial varieties. Perhaps additional provision should be made for pollen varieties for McIntosh. As a rule most orchardists will want a few early or odd varieties for home use or a local market. A mixture of these varieties, together with a few hives of bees, should be of value in insuring adequate pollination. The Red Astrachan is exceptionally fertile with McIntosh and Duchess is a good pollen variety with Spy and Delicious. The planting of compatible, early blooming varieties at the rate of several per acre would be of considerable value if large blocks of a single commercial variety are set.

In an old orchard of a single variety that is bearing poor crops it is not advisable to top work extensively with scions from pollen varieties until other factors have been considered. Perhaps an application of several pounds of nitrate of soda per tree

before blossoming time would prevent an excessive drop of fruit. The need of better pollination could easily be tested by hand-pollinating several hundred flowers as described in this bulletin with a variety known to be compatible and comparing the set with an equal number of flowers which have been pollinated by insects. In both cases blossoms should be thinned to one per cluster. The presence of honey bees undoubtedly increases the set of blossoms and in case other insects were not abundant the honey bees would be necessary to insure an adequate crop.

LITERATURE CITED.

1. Alderman, W. H., 1917. Experimental work on self-sterility of the apple. Proc. Amer. Soc. Hort. Sci. p. 94-101.
2. Auchter, E. C., 1921. Apple pollen and pollination studies in Maryland. Proc. Amer. Soc. Hort. Sci. p. 51-80.
3. Crandall, C. S., 1921. Results from Self-pollination of apple flowers. Proc. Amer. Soc. Hort. Sci. p. 95-100.
4. Dorsey, M. J., 1921. The set of fruit in apple crosses. Proc. Amer. Soc. Hort. Sci. p. 82-94.
5. Gowen, J. W., 1920. Self-sterility and cross sterility in the apple. Maine Agr. Exp. Sta. Bul. 287, p. 61-88.
6. Heinicke, A. J., 1917. Factors influencing the abscission of flowers and partially developed fruits of the apple *(Pyrus malus* L.) Cornell Agr. Exp. Sta. Bul. 393, p. 43-112.
7. Hendrickson, A. H., 1919. Plum pollination. Cal. Agr. Exp. Sta. Bul. 310, p. 3-28.
8. Lewis, C. I., and Vincent, C. C., 1909. Pollination of the apple. Ore. Agr. Exp. Sta. Bul. 104, p. 3-40.
9. Morris, O. M., 1921. Studies in apple pollination. Wash. Agr. Exp. Sta. Bul. 163, p. 4-32.
10. Tufts, W. P., 1919. Almond pollination. Cal. Agr. Exp. Sta., Bul. 306, p. 337-366.
11. ————————, 1919. Pollination of the Bartlett pear. Cal. Agr. Exp. Sta. Bul. 307, p. 369-390.